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CHEMISTRY
HIGHER LEVEL
PAPER 2

Candidate session number

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Tuesday 8 May 2012 (afternoon)

2 hours 15 minutes

Examination code

2	2	1	2	–	6	1	1	4

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer two questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Chemistry*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[90 marks]*.

30 pages

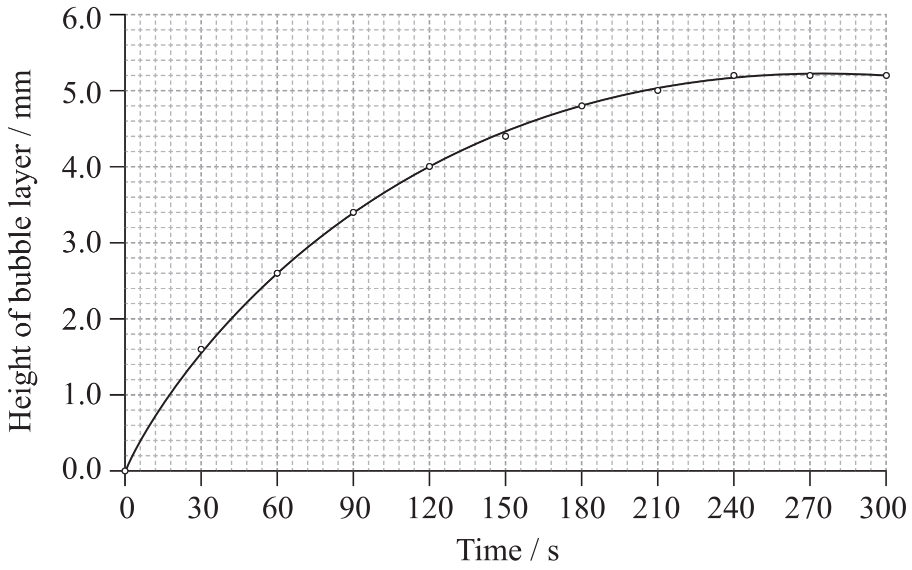
SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. Hydrogen peroxide, $H_2O_2(aq)$, releases oxygen gas, $O_2(g)$, as it decomposes according to the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

50.0 cm^3 of hydrogen peroxide solution was placed in a boiling tube, and a drop of liquid detergent was added to create a layer of bubbles on the top of the hydrogen peroxide solution as oxygen gas was released. The tube was placed in a water bath at 75 °C and the height of the bubble layer was measured every thirty seconds. A graph was plotted of the height of the bubble layer against time.



(a) Explain why the curve reaches a maximum. *[1]*

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(Question 1 continued)

(b) Use the graph to calculate the rate of decomposition of hydrogen peroxide at 120 s. *[3]*

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(c) The decomposition of hydrogen peroxide to form water and oxygen is a redox reaction.

(i) Deduce the oxidation numbers of oxygen present in each of the species below. *[2]*

Species	**Oxidation number of oxygen**
H_2O_2	
H_2O	
O_2	

(ii) State two half-equations for the decomposition of hydrogen peroxide. *[2]*

Oxidation:

. . . .

Reduction:

. . . .

2. A student added 7.40×10^{-2} g of magnesium ribbon to $15.0\ cm^3$ of $2.00\ mol\,dm^{-3}$ hydrochloric acid. The hydrogen gas produced was collected using a gas syringe at 20.0 °C and 1.01×10^5 Pa.

(a) State the equation for the reaction between magnesium and hydrochloric acid. *[1]*

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(b) Determine the limiting reactant. *[3]*

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(c) Calculate the theoretical yield of hydrogen gas:

(i) in mol. *[1]*

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(ii) in cm^3, under the stated conditions of temperature and pressure. *[2]*

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(Question 2 continued)

(d) The actual volume of hydrogen measured was lower than the calculated theoretical volume. Suggest **two** reasons why the volume of hydrogen gas obtained was less. *[2]*

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3. Lattice enthalpies can be determined experimentally using a Born–Haber cycle and theoretically using calculations based on electrostatic principles.

(a) The experimental lattice enthalpies of the chlorides of lithium, LiCl, sodium, NaCl, potassium, KCl, and rubidium, RbCl, are given in Table 13 of the Data Booklet. Explain the trend in the values. *[2]*

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(b) Explain why magnesium chloride, $MgCl_2$, has a much greater lattice enthalpy than sodium chloride, NaCl. *[2]*

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(Question 3 continued)

(c) (i) Identify the process labelled **a** on the Born–Haber cycle for the determination of the standard enthalpy of formation of lithium fluoride, LiF. *[1]*

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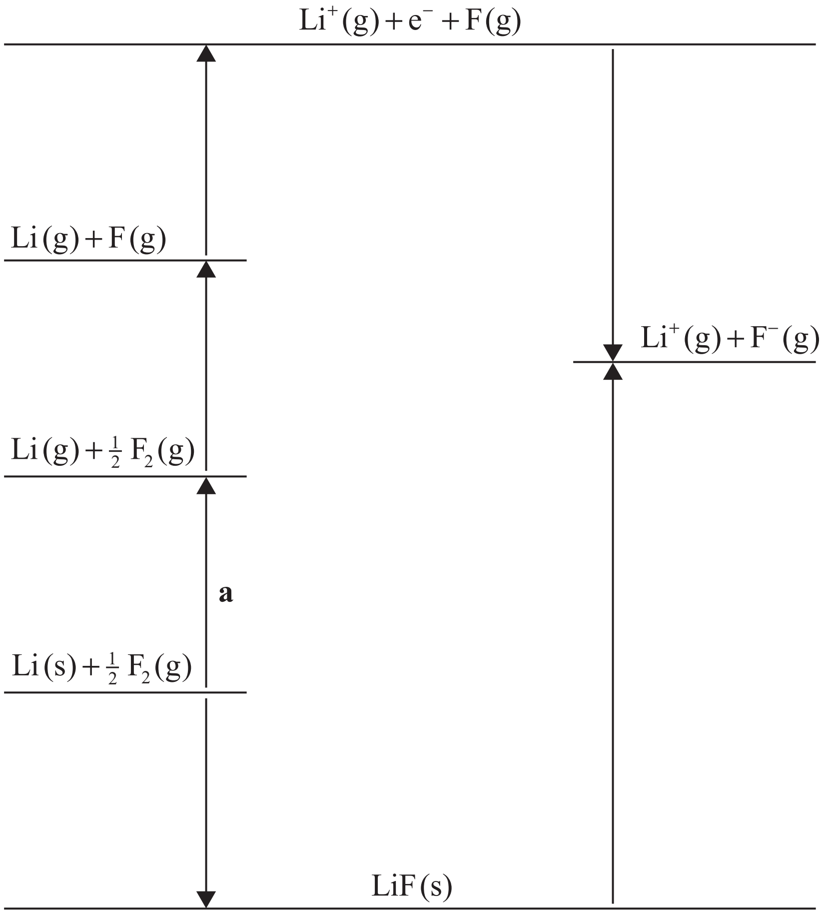

(ii) The enthalpy change for process **a** is $+159\ kJ\,mol^{-1}$. Calculate the standard enthalpy of formation of lithium fluoride, LiF, using this and other values from the Data Booklet. *[2]*

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4. Draw the Lewis structures, predict the shape and deduce the bond angles for xenon tetrafluoride and the nitrate ion. *[6]*

Species	**Lewis structure**	**Shape**	**Bond angle**
XeF_4			
NO_3^-			

5. (a) ^{131}I is a radioactive isotope of iodine.

(i) Define the term *isotope*. *[1]*

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(ii) Identify **one** use of iodine-131 in medicine and explain why it is potentially dangerous. *[2]*

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(b) Discuss the use of carbon-14 in carbon dating. *[3]*

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will not be marked.

6. State and explain whether solutions of each of the following compounds are acidic, basic or neutral. *[4]*

$Cr(NO_3)_3$:

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CH_3COONH_4:

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SECTION B

*Answer **two** questions. Write your answers in the boxes provided.*

7. (a) An organic compound, **X**, with a molar mass of approximately 88 g mol^{-1} contains 54.5 % carbon, 36.3 % oxygen and 9.2 % hydrogen by mass.

(i) Distinguish between the terms *empirical formula* and *molecular formula*. *[2]*

Empirical formula:

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. . . .

Molecular formula:

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(ii) Determine the empirical formula of **X**. *[2]*

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(iii) Determine the molecular formula of **X**. *[1]*

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(This question continues on the following page)

(Question 7 continued)

(iv) **X** is a straight-chain carboxylic acid. Draw its structural formula. *[1]*

(v) Draw the structural formula of an isomer of **X** which is an ester. *[1]*

(vi) The carboxylic acid contains two different carbon-oxygen bonds. Identify which bond is stronger and which bond is longer. *[2]*

Stronger bond:

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Longer bond:

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(This question continues on the following page)

(Question 7 continued)

(vii) Predict and explain the bond lengths and bond strengths of the carbon-oxygen bonds in $CH_3CH_2COO^-$. *[3]*

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(b) (i) State the meaning of the term *hybridization*. *[1]*

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(ii) Describe the hybridization of the carbon atom in methane and explain how the concept of hybridization can be used to explain the shape of the methane molecule. *[3]*

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(This question continues on the following page)

(Question 7 continued)

(iii) Identify the hybridization of the carbon atoms in diamond and graphite and explain why graphite is an electrical conductor. *[3]*

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(c) (i) Aluminium chloride, Al_2Cl_6, does not conduct electricity when molten but aluminium oxide, Al_2O_3, does. Explain this in terms of the structure and bonding of the two compounds. *[4]*

Al_2Cl_6:

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Al_2O_3:

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(ii) Describe the reaction between aluminium chloride and water. *[2]*

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8. (a) The equation for the reaction between sodium hydroxide, NaOH, and nitric acid, HNO_3, is shown below.

$$NaOH\,(aq) + HNO_3\,(aq) \rightarrow NaNO_3\,(aq) + H_2O\,(l) \qquad \Delta H = -57.6\ \text{kJ mol}^{-1}$$

(i) Sketch and label an enthalpy level diagram for this reaction. *[3]*

(ii) Deduce whether the reactants or the products are more energetically stable, stating your reasoning. *[1]*

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(iii) Calculate the change in heat energy, in kJ, when $50.0\ \text{cm}^3$ of $2.50\ \text{mol dm}^{-3}$ sodium hydroxide solution is added to excess nitric acid. *[2]*

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(This question continues on the following page)

(Question 8 continued)

(b) When ammonium chloride, $NH_4Cl(aq)$, is added to excess solid sodium carbonate, $Na_2CO_3(s)$, an acid–base reaction occurs. Bubbles of gas are produced and the solid sodium carbonate decreases in mass. State **one** difference which would be observed if nitric acid, $HNO_3(aq)$, was used instead of ammonium chloride. *[1]*

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(c) When 5.35 g ammonium chloride, $NH_4Cl(s)$, is added to 100.0 cm^3 of water, the temperature of the water decreases from 19.30 °C to 15.80 °C. Determine the enthalpy change, in kJ mol^{-1}, for the dissolving of ammonium chloride in water. *[3]*

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(This question continues on the following page)

(Question 8 continued)

(d) A solution of ammonia has a concentration of $0.500\ mol\,dm^{-3}$.

Calculate the pH of the ammonia solution using information from Table 15 of the Data Booklet. State **one** assumption made. *[4]*

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(e) A buffer solution is made using $25.0\ cm^3$ of $0.500\ mol\,dm^{-3}$ nitric acid, $HNO_3(aq)$, and $25.0\ cm^3$ of $1.00\ mol\,dm^{-3}$ ammonia solution, $NH_3(aq)$.

(i) State the meaning of the term *buffer solution*. *[1]*

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(ii) Calculate the concentrations of ammonia and ammonium ion in the buffer solution. *[2]*

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(This question continues on the following page)

(Question 8 continued)

(iii) Determine the pH of the buffer solution at 25 °C. *[2]*

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(iv) Explain why the pH of the buffer solution is different from the pH of the ammonia solution calculated in (d). *[1]*

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(v) Explain the action of the buffer solution when a few drops of nitric acid solution are added to it. *[2]*

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(This question continues on the following page)

(Question 8 continued)

(f) Bromocresol green is an acid–base indicator. Information about bromocresol green is given in Table 16 of the Data Booklet.

(i) Identify the property of bromocresol green that makes it suitable to use as an acid–base indicator. *[1]*

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(ii) State and explain the relationship between the pH range of bromocresol green and its pK_a value. *[2]*

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9. (a) Transition metals exhibit variable oxidation states in their complexes.

(i) State the **full** electron configuration of Fe. *[1]*

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(ii) State the **abbreviated** electron configuration of Fe^{3+} ions. *[1]*

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(iii) Cyanide ions, CN^-, can act as ligands. One complex ion that involves the cyanide ion is $[Fe(CN)_6]^{3-}$. Identify the property of a cyanide ion which allows it to act as a ligand, and explain the bonding that occurs in the complex ion in terms of acid–base theory. Describe the structure of the complex ion, $[Fe(CN)_6]^{3-}$. *[4]*

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(This question continues on the following page)

(Question 9 continued)

(iv) Explain why complexes of Fe^{3+} are coloured. *[2]*

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(b) The Contact process converts $SO_2(g)$ to $SO_3(g)$ during the production of sulfuric acid. The reaction is exothermic.

(i) State the equation for the production of $SO_3(g)$ from $SO_2(g)$. *[1]*

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(ii) Identify a catalyst used in the Contact process. *[1]*

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(iii) Explain the effect of the catalyst on the reaction rate. *[2]*

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(This question continues on the following page)

(Question 9 continued)

(iv) Catalysts are very expensive. Suggest **two** economic benefits of using the catalyst to speed up the reaction in the Contact process. *[2]*

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(v) Predict and explain whether entropy increases or decreases during the formation of SO_3. *[2]*

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(vi) State and explain whether the formation of SO_3 is more spontaneous or less spontaneous at higher temperatures. *[3]*

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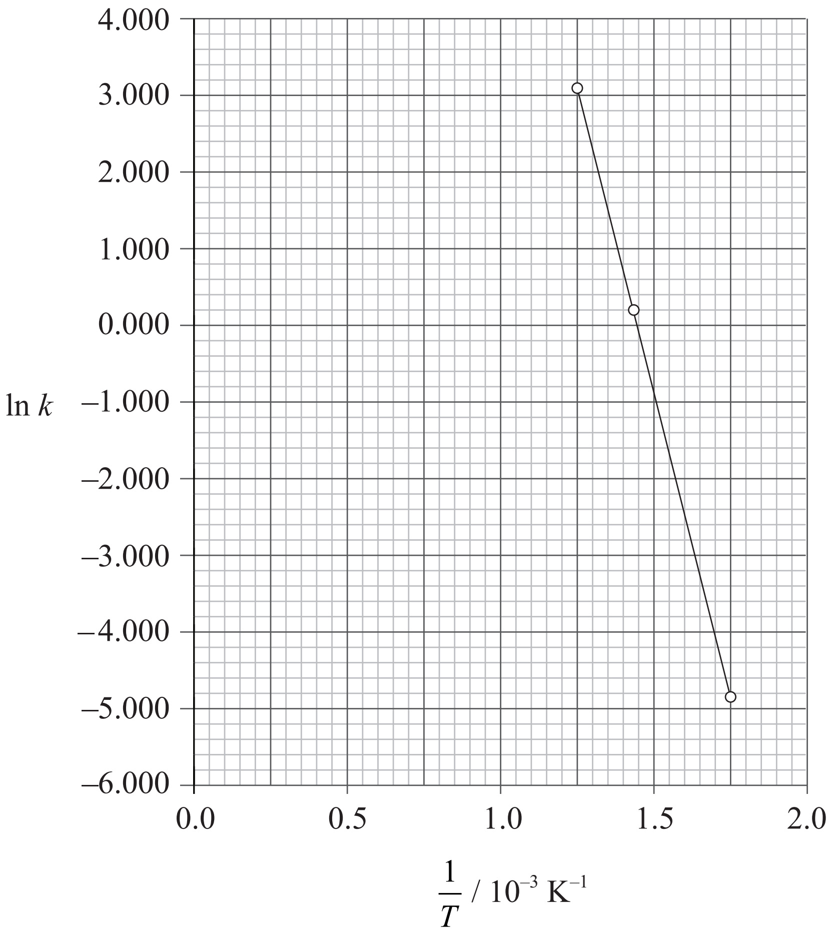
(This question continues on the following page)

(Question 9 continued)

(c) The reaction between carbon monoxide, $CO(g)$, and nitrogen dioxide, $NO_2(g)$, was studied at different temperatures and a graph was plotted of $\ln k$ against $\frac{1}{T}$. The equation of the line of best fit was found to be:

$$\ln k = -1.60 \times 10^4 \left(\frac{1}{T}\right) + 23.2$$



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(Question 9 continued)

(i) The Arrhenius equation is shown in Table 1 of the Data Booklet. Identify the symbols k and A. *[2]*

k: . . . .

A: . . . .

(ii) Calculate the activation energy, E_a, for the reaction between CO(g) and NO_2(g). *[2]*

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(iii) Calculate the numerical value of A. *[2]*

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10. (a) Esters and amides can be produced by condensation reactions.

(i) State the names of **two** organic compounds required to produce ethyl methanoate and state suitable reaction conditions. *[2]*

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(ii) Deduce the structure of the simplest repeating unit of the polymer formed from the reaction between 1,6-diaminohexane and hexane-1,6-dioic acid and state **one** use of this product. *[3]*

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(This question continues on the following page)

(Question 10 continued)

(b) Under certain conditions but-2-ene can react with water to form butan-2-ol.

(i) Identify a suitable catalyst for this reaction. *[1]*

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(ii) But-2-ene can be converted to 2-bromobutane and then to butan-2-ol as follows:

$$CH_3CH{=}CHCH_3 \xrightarrow{\textbf{I}} CH_3CH(Br)CH_2CH_3 \xrightarrow{\textbf{II}} CH_3CH(OH)CH_2CH_3$$

Identify the reagent(s) and conditions necessary for each of the steps **I** and **II**. *[4]*

Step **I**:

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Step **II**:

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(iii) State and explain how the rate of step **II** would differ if 2-chlorobutane was used instead of 2-bromobutane. *[1]*

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(This question continues on the following page)

(Question 10 continued)

(c) Halogenoalkanes can be classified as primary, secondary or tertiary.

(i) State the meaning of the term *isomers*. *[1]*

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(ii) Deduce the structural formulas of 2-bromobutane and 1-bromo-2-methylpropane, and identify each molecule as primary, secondary or tertiary. *[4]*

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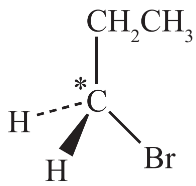
(Question 10 continued)

(d) 1-bromopropane undergoes a substitution reaction with potassium cyanide.



(i) Explain why the substitution occurs on the carbon atom that is marked as *C. *[1]*

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(ii) Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs during the substitution. *[4]*

(This question continues on the following page)

(Question 10 continued)

(iii) Deduce the reagent(s) and catalyst needed to convert the product of the substitution reaction to an amine. *[2]*

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(e) 1-bromopropane reacts with sodium hydroxide dissolved in hot ethanol when heated under reflux. State an equation for the reaction. *[2]*

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